NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 3475

AN ANALYSIS OF ACCELERATION, AIRSPEED, AND GUST-VELOCITY DATA FROM ONE TYPE OF FOUR-ENGINE TRANSPORT AIRPLANE OPERATED OVER TWO DOMESTIC ROUTES

By Martin R. Copp and Thomas L. Coleman

Langley Aeronautical Laboratory
Langley Field, Va.

Washington
October 1955

NATIONAL ADVISORY COMMITTEE FOR AERONAUTIC

TECHNICAL NOTE 3475

AN ANALYSIS OF ACCELERATION, AIRSPEED, AND GUST-VELOCITY DATA FROM ONE TYPE OF FOUR-ENGINE TRANSPORT AIRPLANE OPERATED OVER TWO DOMESTIC ROUTES

By Martin R. Copp and Thomas L. Coleman

SUMMARY

Time-history data obtained by the NACA VGH recorder from two four-engine commercial transport airplanes of the same type operating on two domestic routes are analyzed to determine the magnitude and frequency of occurrence of gusts and of gust and maneuver accelerations and the associated airspeeds. The number of gust accelerations experienced per mile of flight by the two operations differed by a factor of roughly 3. The number of gusts per mile of flight differed by a factor of roughly 4. A general decrease in the frequency of occurrence of gusts of a given velocity with increasing altitude was noted for both operations. For acceleration values above 0.8g, maneuver accelerations formed a substantial part of the total-flight load histories. A comparison of the average overall airspeeds and the corresponding average airspeeds in rough air (with accelerations equal to or greater than 0.3g) indicated very little slowdown by either operation upon encountering turbulence.

INTRODUCTION

As part of a continuing study of the gust and load histories for transport airplanes (see, for example, refs. 1 and 2), samples of VGH records have been obtained from two four-engine commercial transport airplanes. The type of airplane from which the data were obtained has been in wide use by both foreign and domestic operators since about 1948. The data samples represent 839 and 1,080 flight hours of operation on two transcontinental routes and cover operations up to an altitude of 25,000 feet.

The VGH data have been analyzed to determine the magnitude and frequency of occurrence of gusts and of gust and maneuver accelerations and the associated airspeeds and altitudes for each of the operations.

The variations in the magnitude and frequency of occurrence of the accelerations and gusts with route, flight condition, and altitude are presented. In addition, previously published V-G data (ref. 3) from one operation are used to supplement one set of the present VGH data to obtain an estimate of the overall gust and acceleration history.

INSTRUMENTATION AND AIRPLANE

The data were collected with NACA VGH recorders which are described in detail in reference 4. This recorder yields a time-history record of indicated airspeed, altitude, and normal acceleration from which the detailed load and gust history of the airplane, together with pertinent operating conditions such as airspeeds and altitudes, can be obtained.

The data were obtained on two transport airplanes of the same type although there were slight differences between the gross weight and several other characteristics of these particular airplanes due to variations in the fuel-tank arrangements and the types of propellers. The characteristics of the two airplanes (designated A and B) that are pertinent to the evaluation of the data are described in the following table:

Design gross weight, W, lb	
Airplane A	89,900
Airplane B	93,200
Wing area, S, sq ft	1,463
Aspect ratio, A	9.4
Span, b, ft	117.5
Mean aerodynamic chord, $\bar{c}$, ft	13.7
Slope of lift curve per radian (computed), m	4.95
Design speed for maximum gust intensity (indicated), V_B, mph	
Airplane A	183
Airplane B	187
Design cruising speed (indicated), V_C, mph	300
Limit-gust-load-factor increment (computed)	
Airplane A	1.54
Airplane B	1.47
Gust alleviation factor, K, for gross weight (ref. 5)	
Airplane A	1.218
Airplane B	1.212

The values listed in the table were obtained from the airplane operators unless otherwise indicated. The slope of the lift curve was calculated (as recommended in ref. 6) from the relation $\frac{6A}{A + 2}$, where A is the aspect ratio. The limit-gust-load-factor increments were computed according to current Civil Air Regulations (ref. 5). The values are based on the design gross weights and an effective gust velocity U_e (ref. 6) of 30K fps at the design cruising speed V_C of 300 mph. The computed gust-load factors are not necessarily the design values, since the lift-curve slope used by the manufacturer is slightly different from the value used herein.

SCOPE OF DATA

The routes on which airplanes A and B were flown are shown in figure 1 and are designated as operation A and operation B to correspond to the airplane designations. The samples of VGH data probably represent operations over all sections of the routes shown although the amount of flight time over each section of the routes is not known.

The operating conditions covered by the data and the sample size from each operation are summarized in the following table:

	Operation A	Operation B
Average length of flight, hr	1.95	2.15
Average cruising altitude, ft	14,100	14,900
Average indicated airspeed, mph	227.9	216.5
Total record hours evaluated	838.7	1,080.3
Dates of record collection	1950 to 1953	1951 to 1954

EVALUATION OF RECORDS

The VGH records from each operation were evaluated in accordance with the methods used in references 1 and 2 to obtain frequency distributions of gust and maneuver accelerations and the associated airspeeds. For these evaluations, each flight on the VGH records was divided into three flight conditions: climb, en route, and descent. The climb condition covered the time from take-off until the airplane began to maintain level flight, as indicated by the altitude trace. The descent was considered to begin when the airplane began to lose altitude consistently and to end when the airplane touched down. The portion of the flight between the climb and descent was considered to be the en-route condition and ordinarily it contained some changes in altitude.

Since accelerations caused by both gusts and maneuvers were present on the records, it was necessary to distinguish between the two types of accelerations. The criterion used was that maneuver accelerations generally have a longer period (usually greater than 4 seconds) than gust accelerations, and that high-frequency low-intensity fluctuations of the airspeed trace occur simultaneously with the gust accelerations but are not apparent during maneuvers. (See illustrations of VGH records in ref. 2.)

The maneuver and gust accelerations were read from the VGH time-history records by using the steady-flight position of the acceleration trace as a reference. The evaluation of the gust accelerations was limited to values equal to or greater than ±0.3g since reading to a lower level would have greatly increased the evaluation time without yielding a corresponding increase in the value of the data. Only the peak or maximum value was read for each deflection of the acceleration trace greater than the given threshold value. The indicated airspeed and pressure altitude corresponding to each gust acceleration were also read and tabulated.

In evaluating the maneuvers, a reading threshold of ±0.1g was used. As in reference 2, the maneuver accelerations were divided into two groups, that is, check-flight maneuvers obtained from airplane or pilot check flights and operational maneuvers obtained from routine operational flights.

Distributions of airspeed and altitude were obtained from the records by reading and tabulating the indicated airspeed and pressure altitude for each 1-minute interval of flight.

The following table indicates the number of flight hours of record from which the various distributions of airspeed, altitude, and accelerations were read:

	Operation A	Operation B
Total record hours available	838.7	1,080.3
Hours evaluated for gust accelerations, airspeeds, and altitudes	833.5	1,061.8
Hours evaluated for check-flight maneuvers	838.7	1,080.3
Hours actually spent in check flights . . .	5.2	18.5
Hours evaluated for operational maneuvers	833.5	1,036.1

Gust accelerations and the corresponding altitudes and airspeeds were used to calculate gust velocities by means of the derived gust-velocity equation (see ref. 7):

$$U_{de} = \frac{2Wa_n}{K_g \rho_o V_e m S}$$

where

U_{de} derived gust velocity, fps

W airplane weight, lb

a_n normal acceleration, g units (corresponds to Δn used in ref. 7)

K_g gust factor

ρ_o air density at sea level, slugs/cu ft

V_e equivalent airspeed, fps

m slope of lift curve per radian

S wing area, sq ft

The gust factor K_g is a function of the mass ratio of the airplane and, consequently, it varies with altitude. The values of K_g were computed at the midpoint of each 5,000-foot altitude range and varied from 0.710 at 2,500 feet to 0.790 at 22,500 feet. An average weight of 0.85 design gross weight was assumed in determining the values of K_g and in calculating the gust velocities.

RESULTS

The frequency distributions of accelerations and gust velocities evaluated from the VGH records are given in tables I to V and are grouped in class intervals of 0.1g for acceleration and 4 fps for gust velocity. The number of flight hours and the flight miles represented by each distribution are also given in the tables.

The gust-acceleration distributions for each operation (table I) are plotted in figure 2 in terms of the average number of accelerations greater than a given value per mile of flight. For this purpose, the positive and negative acceleration distributions for each operation were combined into a single distribution without regard to sign since they were essentially symmetrical. The cumulative frequency per mile, given as the ordinate in figure 2, was obtained by progressively summing (starting with the frequency of the largest acceleration) the combined frequency distributions to obtain the cumulative frequency $\sum f$. The cumulative frequencies were then divided by the number of flight miles l represented by the data to obtain the average number of accelerations greater than given values which were experienced per mile of flight, $\sum f/l$.

The gust-acceleration data by flight condition (that is, climb, en route, and descent) from table II are shown in figure 3 for each operation. As in figure 2, the ordinate scale is in terms of the number of accelerations greater than a given value per mile of flight.

The frequency of occurrence of operational- and check-flight-maneuver accelerations (table III) is plotted in figure 4 for both operations. In order to compare the magnitude and frequency of occurrence of gust and maneuver accelerations, the gust-acceleration data of figure 2 and the combined maneuver distributions of figure 4 are plotted in figure 5. The combined maneuver distribution for each operation was obtained by summing the ordinate values of the positive and negative check-flight- and operational-maneuver distributions presented in figure 4.

The frequency of occurrence of gusts of a given velocity is plotted in figure 6 for each operation. The data for the figure were taken from table IV. In figure 7, the frequency of occurrence of gusts of a given velocity for various altitude ranges is plotted for each operation. The data plotted in the figure were obtained from table V which gives the gust-velocity distributions by 5,000-foot altitude ranges. Because of the small sample size available for the highest altitudes, the gust-velocity distributions for the 20,000-foot to 25,000-foot altitude range were not plotted in figure 7. The apparent dropoff in gust frequency at low values of gust velocity in figures 6 and 7 is due to incomplete frequency counts near the threshold values.

For the purpose of examining the airspeed practices of each operation, the portion of total flight time spent at given indicated airspeeds in each flight condition is plotted in figure 8. The distributions were obtained from the 1-minute airspeed tabulations of the VGH data. In order to compare those data with the airspeeds used in rough air, the airspeeds at which the gust accelerations greater than $\pm 0.3g$ were encountered are also shown for each flight condition by the dashed lines. In addition, the design speed for maximum gust intensity V_B and the design cruising speed V_C are shown in figure 8.

PRECISION AND RELIABILITY OF RESULTS

The three possible sources of error in the present data are instrument errors, installation errors, and reading errors. Reference 4 gives a discussion of the inherent errors in the NACA VGH recorder and the installation errors. The installations met the basic requirements given in reference 4, and the installation errors for the NACA VGH instruments used in the present investigation were, accordingly, believed to be negligible. A discussion of the reading errors which apply to the present data is given in reference 8. The estimated total error for each of the quantities measured is:

Acceleration, g units	±0.05
Indicated airspeed, mph	
At 100 mph	±5.0
At 250 mph	±2.5
Pressure altitude, ft	
At 2,000 ft	±150
At 20,000 ft	±300

In addition to the precision of the instrument and the accuracy of the record reading, the statistical reliability of the data sample (that is, how representative it is of extended periods of operations) is also important. Some rough estimates of the statistical reliability of the present samples were obtained by observing the variations between the distributions from individual records and from combinations of records forming the total sample. Based on these comparisons, the total distributions of gust accelerations and gusts (figs. 2 and 6) are estimated to be reliable within a factor of about 2 on the ordinate scale at the smaller acceleration and gust-velocity values and within a factor of 3 at the higher values. The distributions of the data by altitude and flight condition are somewhat less reliable, however, since they represent smaller data samples.

The operational-maneuver acceleration distributions given in figure 4 are estimated to be reliable within a factor of about 3 for the range of data shown. The reliability of the check-flight-maneuver data (fig. 4) may be somewhat less, however, because of the small number of hours spent in check flights (table III(b)). The amounts of time spent in check flights were 0.62 percent and 1.71 percent of the total flight hours for operations A and B, respectively. Information received from airline operators indicated that, for extended operations, about 1 percent of the total flight time is spent in airplane and pilot check flights. The percentage of total time spent in check flights appears, therefore, to be representative of current operations.

DISCUSSION

Gust Accelerations

Inspection of figure 2 shows that, except for the lowest acceleration value, roughly three times the number of gust accelerations per mile of flight were experienced in operation B as were experienced in operation A. This difference corresponds to the accelerations for operation B being about 20 percent higher than those for operation A when the comparison is made for a given frequency of occurrence. The variations in the number and magnitude of the accelerations experienced in the two operations are due mainly to differences in the number of gusts encountered and the airspeeds at which the gusts were encountered.

The breakdown of the VGH gust-acceleration distributions into three flight conditions (fig. 3) indicates that, in general, for both operations, the greatest number of accelerations per mile of flight were encountered during the descent condition and the least number during the en-route or cruise condition. The fewer accelerations experienced during the cruise condition are due to the decrease in gust frequency with increasing altitude, as is discussed subsequently. Although both the climb and descent conditions are associated with the more turbulent air at low altitudes, the higher airspeeds utilized during descent resulted in higher accelerations for this condition than for the climb. An examination of table II indicates that more than 50 percent of the total number of accelerations above 0.3g occurred during the descent for operation A and more than 40 percent during the descent for operation B. A reduction in airspeed during the descent, therefore, would result in a substantial reduction in the number of accelerations above 0.3g for the total operation.

Maneuver Accelerations

Figure 4 shows that the positive and negative operational-maneuver acceleration distributions are approximately symmetrical for both operations. The maximum operational-maneuver accelerations experienced were 0.5g and 0.6g for operations A and B, respectively. The distributions indicate maximum differences of 3:1 in the frequency of occurrence of operational-maneuver accelerations for the two operations. The magnitude and frequency of occurrence of operational-maneuver accelerations are in general agreement with previous data obtained from several types of commercial transport airplanes and reported in references 1 and 2.

Inspection of figure 4 shows that the magnitude and frequency of occurrence (based on total flight miles) of check-flight-maneuver accelerations were somewhat greater for operation B than for operation A.

This difference may result from the greater percentage of total flight time spent in check flights by operation B, as was previously noted. The positive and negative acceleration distributions for operation A are essentially symmetrical, whereas for operation B the positive accelerations were larger, with the maximum acceleration being approximately 1.4g. This value is higher than the maximum acceleration obtained on several types of transport airplanes previously reported in references 1 and 2.

Comparison of the accelerations (fig. 5) caused by gusts and by maneuvers (operational and check flight) indicates that accelerations below about 0.8g resulted several times more frequently from gusts than from maneuvers. In contrast, accelerations above 0.8g appear to have resulted at least as frequently from maneuvers as from gusts. For operation A, the maximum gust and maneuver accelerations recorded in the present data samples were approximately equal, whereas for operation B, the maximum maneuver acceleration was about 40 percent higher than the maximum gust acceleration. As previously noted, these large maneuver accelerations for airplane B occurred during check flights. The data in figure 5 indicate therefore that, for the larger values of acceleration, maneuver accelerations may be a substantial part of the total-flight load histories.

Gust Velocities

Figure 6 indicates overall differences of about 4:1 in the frequency of occurrence of gusts for the two operations, with the higher number occurring for operation B. For a given frequency of occurrence, this results in the magnitudes of the larger gust velocities for operation B being approximately 30 percent higher than those for operation A. A consideration of the topography covered by the two routes suggests that a larger percentage of the flight miles was over higher and rougher terrain for operation B than for operation A. Under these conditions, a higher gust experience would be normally expected for operation B, assuming all other phases of the two operations were equal.

Previous results of gust experiences obtained on the two routes in 1937 to 1941 with twin-engine airplanes (operations E-I and E-V in ref. 9) indicate a higher gust experience for the route covered by operation A. Although the reason for the apparent discrepancy between the present results and those of reference 9 is not known, it may be associated with changes in airline equipment and operating practices.

The variation in the frequency of occurrence of gusts of a given velocity with pressure altitude is indicated in figure 7. The results show that, for both operations, the number of gusts encountered per mile of flight decreases with increasing altitude. For operation A, the frequency of occurrence of gust velocities of a given value for the 0- to 5,000-foot altitude range is roughly 100 times that for the 15,000- to 20,000-foot range. In the case of operation B, the corresponding difference between the gust frequencies is about 15:1. The smaller reduction in gust frequency with increasing altitude indicated for operation B might result from the apparent lower altitude above terrain for this operation; this factor was not considered in grouping the data in the altitude ranges.

Airspeeds

In figure 8, the overall distributions of indicated airspeed for both operations show that the highest speeds occurred during the descent and that the climb speeds generally were the lowest. The design cruising speed V_C of 300 mph was equaled in operation B and exceeded several times in operation A in the descent condition.

Figure 8 also shows that a large part of the airspeeds in rough air for the climb condition was approximately equal to or less than the design speed for maximum gust intensity V_B. A reduction in airspeed upon entering rough air was not required, therefore, in many cases during the climb for both operations. For the en-route and descent conditions, figure 8 indicates very little reduction in airspeed upon encountering rough air. The rough-air distributions of figure 8 were based on the aircraft experiencing accelerations equal to or greater than 0.3g. For higher values of acceleration, a substantial airspeed reduction might be expected. However, an additional breakdown of the VGH data indicated that, for values of gust acceleration equal to or greater than 0.5g, no appreciable slowdown was evident for the three flight conditions of both operations. As indicated in reference 1, this might be due to either the pilot's not anticipating the turbulence in time to reduce the airspeed or to a practice of not reducing the airspeed unless turbulence more severe than represented in the present data is encountered.

In order to examine the effect of airspeeds on the gust-acceleration experiences for the two operations, the average indicated airspeeds in rough air $\left(a_n \geqq 0.3g\right)$ for the three flight conditions have been obtained from figure 8 and are presented in the following table:

Operation	Indicated airspeed, mph, for -			
	Climb	En route	Descent	Total flight
A	197.0	232.2	239.0	234.9
B	192.3	218.1	221.2	216.8

From the table it can be seen that the average rough-air speed for all flight conditions in operation B is approximately 8 percent lower than in operation A. It would appear that the lower, average rough-air speed would result in the accelerations for operation B being lower than those for operation A. This is offset, however, by the 30 percent higher gust velocities (fig. 6) which result in the accelerations for operation B being about 20 percent higher than for operation A when the comparison is made for a given frequency of occurrence.

Overall Load and Gust Histories

Samples of VGH data are limited in size and therefore do not contain many of the larger loads and gust velocities which occur rather infrequently. Estimates of these large and infrequent loads and gust velocities are usually based on samples of V-G data covering long periods of operation. By combining the V-G and VGH data, it appears possible to obtain an estimate of the overall load and gust history for a given type of operation. Examples of such estimates are given in references 1 and 8 for previous operations. This procedure has also been followed for operations of the present type of airplane by combining the VGH data for the present operation B with 14,953 hours of V-G data obtained for transports of the same type and operated by the same airline (operation A of ref. 3). The combined acceleration and gust data are shown in figures 9 and 10, respectively.

In figure 9, the overall gust and maneuver-load history was estimated by a curve which was faired through the VGH gust and maneuver data and then extended to match the V-G data at the higher acceleration values. As can be seen from the figure, the V-G data grossly underestimate the frequency of occurrence of the lower acceleration values because of the nature of the record and the evaluation procedure (two readings per record). On the basis of the faired curve, figure 9 indicates that the acceleration corresponding to a gust-load-factor increment of approximately 1.5 is exceeded on the average 1.6×10^{-6} times per mile of flight, or once in every 0.63×10^{6} flight miles.

The VGH gust accelerations alone are also shown in figure 9 for comparison with the overall load history. The contribution of maneuvers to the total load history as discussed previously in connection with figure 5 is evident from a comparison of the two sets of VGH data. A conflict between the VGH gust-acceleration data and the V-G data is also indicated by the trend of the VGH gust accelerations from about 0.8g to 1.0g. This conflict suggests an apparent biasing of the V-G data by maneuver accelerations in spite of efforts to eliminate obvious maneuver accelerations from the V-G data. These difficulties indicate the need for further study of the data.

The faired curve of figure 10 indicates that, in the high range of gust velocities, a 50-fps gust is exceeded on the average 3.6×10^{-6} times per mile of flight, or once in 0.28×10^{6} flight miles. In the lower gust-velocity range, a 30-fps gust is exceeded on the average 1.6×10^{-4} times per mile of flight, or once in 0.63×10^{4} flight miles. As previously noted, maneuvers might have biased the V-G gust-acceleration data and, therefore, the gust velocities given in figure 10, which were derived from the same data, might also be biased.

CONCLUSIONS

An analysis of VGH data obtained from two four-engine commercial transport airplanes of the same type during operations on two domestic routes has indicated the following results:

1. The number of gust accelerations experienced per mile of flight by the two operations differed by a factor of roughly 3. The number of gusts per mile of flight differed by a factor of roughly 4.

2. About 100 times as many gusts were encountered per mile of flight below 5,000 feet as were encountered between 15,000 to 20,000 feet for one operation and about 15 times as many at similar altitudes for the other operation.

3. Accelerations below 0.8g occurred several times more frequently from gusts than from maneuvers. Accelerations above 0.8g appeared to have resulted at least as frequently from maneuvers as from gusts.

4. A composite distribution of VGH and V-G data obtained from one operation indicated that a gust-load-factor increment of 1.50 was exceeded on the average 1.6×10^{-6} times per mile of flight, or once in every 0.63×10^{6} flight miles. In the high range of gust velocities, a 50-fps gust was exceeded on the average 3.6×10^{-6} times per mile of flight, or once in 0.28×10^{6} flight miles. In the lower gust-velocity range, a 30-fps gust was exceeded on the average 1.6×10^{-4} times per mile of flight, or once in 0.63×10^{4} flight miles.

5. The overall distributions of indicated airspeed for both operations showed that the highest speeds occurred during the descent and that the climb speeds generally were the lowest.

6. No appreciable slowdown in rough air was evident for the three flight conditions of both operations.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 1, 1955.

REFERENCES

1. Coleman, Thomas L., Copp, Martin R., Walker, Walter G., and Engel, Jerome N.: An Analysis of Accelerations, Airspeeds, and Gust Velocities From Three Commercial Operations of One Type of Medium-Altitude Transport Airplane. NACA TN 3365, 1955.

2. Coleman, Thomas L., and Copp, Martin R.: Maneuver Accelerations Experienced by Five Types of Commercial Transport Airplanes During Routine Operations. NACA TN 3086, 1954.

3. Walker, Walter G.: Gust Loads and Operating Airspeeds of One Type of Four-Engine Transport Airplane on Three Routes From 1949 to 1953. NACA TN 3051, 1953.

4. Richardson, Norman R.: NACA VGH Recorder. NACA TN 2265, 1951.

5. Anon.: Airplane Airworthiness - Transport Categories. Pt. 4b of Civil Air Regulations, Civil Aero. Board, U. S. Dept. Commerce, Dec. 31, 1953.

6. Donely, Philip: Summary of Information Relating to Gust Loads on Airplanes. NACA Rep. 997, 1950. (Supersedes NACA TN 1976.)

7. Pratt, Kermit G.: A Revised Formula for the Calculation of Gust Loads. NACA TN 2964, 1953.

8. Press, Harry, and McDougal, Robert L.: The Gust and Gust-Load Experience of a Twin-Engine Low-Altitude Transport Airplane in Operation on a Northern Transcontinental Route. NACA TN 2663, 1952.

9. Walker, Walter G.: Summary of Revised Gust-Velocity Data Obtained From V-G Records Taken on Civil Transport Airplanes From 1933 to 1950. NACA TN 3041, 1953.

TABLE I.- FREQUENCY DISTRIBUTIONS OF POSITIVE AND NEGATIVE GUST ACCELERATIONS

Acceleration, a_n, g units	Frequency, f, for -	
	Operation A	Operation B
1.0 to 1.1	-----	1
.9 to 1.0	1	3
.8 to .9	0	3
.7 to .8	1	6
.6 to .7	9	53
.5 to .6	21	155
.4 to .5	86	243
.3 to .4	511	586
-.3 to -.4	651	854
-.4 to -.5	107	203
-.5 to -.6	24	79
-.6 to -.7	6	12
-.7 to -.8	3	5
-.8 to -.9	1	1
-.9 to -1.0	-----	1
Total (positive and negative)	1,421	2,205
Sample size, hr	833.5	1,061.8
Flight miles, l	2.3×10^5	2.8×10^5

TABLE II.- FREQUENCY DISTRIBUTIONS OF GUST ACCELERATIONS BY FLIGHT CONDITION

Acceleration (positive and negative), a_n, g units	Frequency, f, for -					
	Climb		En route		Descent	
	Operation A	Operation B	Operation A	Operation B	Operation A	Operation B
0.3 to 0.4	147	196	353	554	662	690
.4 to .5	15	47	68	201	110	198
.5 to .6	7	23	16	107	22	104
.6 to .7	1	10	5	37	9	18
.7 to .8	---	2	3	3	1	6
.8 to .9	---	0	1	4	---	0
.9 to 1.0	---	1	1	1	---	2
1.0 to 1.1	---	---	---	---	---	1
Total	170	279	447	907	804	1,019
Sample size, hr	102.4	148.4	573.6	714.9	157.5	198.5
Flight miles, l	2.3×10^4	3.1×10^4	16.0×10^4	20.0×10^4	4.2×10^4	4.9×10^4

TABLE III.- FREQUENCY DISTRIBUTIONS OF

MANEUVER ACCELERATIONS

(a) Operational maneuvers

Acceleration, a_n, g units	Frequency, f, for -	
	Operation A	Operation B
0.6 to 0.7	-----	1
.5 to .6	2	2
.4 to .5	4	18
.3 to .4	47	89
.2 to .3	465	636
.1 to .2	2,817	3,962
-.1 to -.2	3,164	5,022
-.2 to -.3	297	733
-.3 to -.4	25	98
-.4 to -.5	3	11
-.5 to -.6	1	5
Total	6,825	10,577
Sample size, hr	833.5	1,036.1
Flight miles, l	2.3×10^5	2.7×10^5

TABLE III.- FREQUENCY DISTRIBUTIONS OF

MANEUVER ACCELERATIONS - Concluded

(b) Check-flight maneuvers

Acceleration, a_n, g units	Frequency, f, for -	
	Operation A	Operation B
1.4 to 1.5	---	1
1.3 to 1.4	---	0
1.2 to 1.3	---	1
1.1 to 1.2	---	1
1.0 to 1.1	---	1
.9 to 1.0	---	1
.8 to .9	2	3
.7 to .8	1	1
.6 to .7	7	3
.5 to .6	4	6
.4 to .5	13	37
.3 to .4	22	54
.2 to .3	180	323
.1 to .2	161	865
-.1 to -.2	200	757
-.2 to -.3	112	282
-.3 to -.4	10	33
-.4 to -.5	4	25
-.5 to -.6	2	7
-.6 to -.7	2	3
-.7 to -.8	---	1
-.8 to -.9	---	2
Total (positive and negative)	720	2,407
Sample size, hr	838.7	1,080.3
Time in check flights, hr	5.2	18.5
Flight miles, l	2.3×10^5	2.8×10^5

TABLE IV.- FREQUENCY DISTRIBUTIONS

OF GUST VELOCITIES

Gust velocity, U_{de}, fps	Frequency, f, for -	
	Operation A	Operation B
8 to 12	389	107
12 to 16	679	1,058
16 to 20	280	590
20 to 24	46	293
24 to 28	16	97
28 to 32	7	34
32 to 36	4	16
36 to 40	-----	7
40 to 44	-----	1
44 to 48	-----	2
Total	1,421	2,205
Sample size, hr	833.5	1,061.8
Flight miles, l	2.3×10^5	2.8×10^5

TABLE V.- FREQUENCY DISTRIBUTIONS OF GUST VELOCITY BY ALTITUDE

Gust velocity, U_{de}, fps	Frequency, f, for -									
	0 to 5,000 ft		5,000 to 10,000 ft		10,000 to 15,000 ft		15,000 to 20,000 ft		20,000 to 25,000 ft	
	Operation A	Operation B	Operation A	Operation B	Operation A	Operation B	Operation A	Operation B	Operation A	Operation B
8 to 12	240	38	104	33	39	30	6	6	--	--
12 to 16	366	362	155	261	84	175	47	242	27	18
16 to 20	205	235	42	192	20	67	5	91	8	5
20 to 24	29	125	7	116	6	22	1	29	3	1
24 to 28	13	26	2	53	1	5	--	13	--	--
28 to 32	5	11	1	7	1	10	--	6	--	--
32 to 36	2	9	1	4	1	1	--	2	--	--
36 to 40	---	2	---	2	---	2	--	1	--	--
40 to 44	---	0	---	1	---	0	--	---	--	--
44 to 48	---	1	---	---	---	1	--	---	--	--
Total	860	809	312	669	152	313	59	390	38	24
Sample size, hr	120.4	129.2	147.6	195.5	245.2	242.6	290.4	468.9	29.9	25.6
Flight miles, l	2.7×10^4	2.4×10^4	3.8×10^4	4.8×10^4	6.8×10^4	6.4×10^4	8.4×10^4	13.0×10^4	8.9×10^3	7.8×10^3

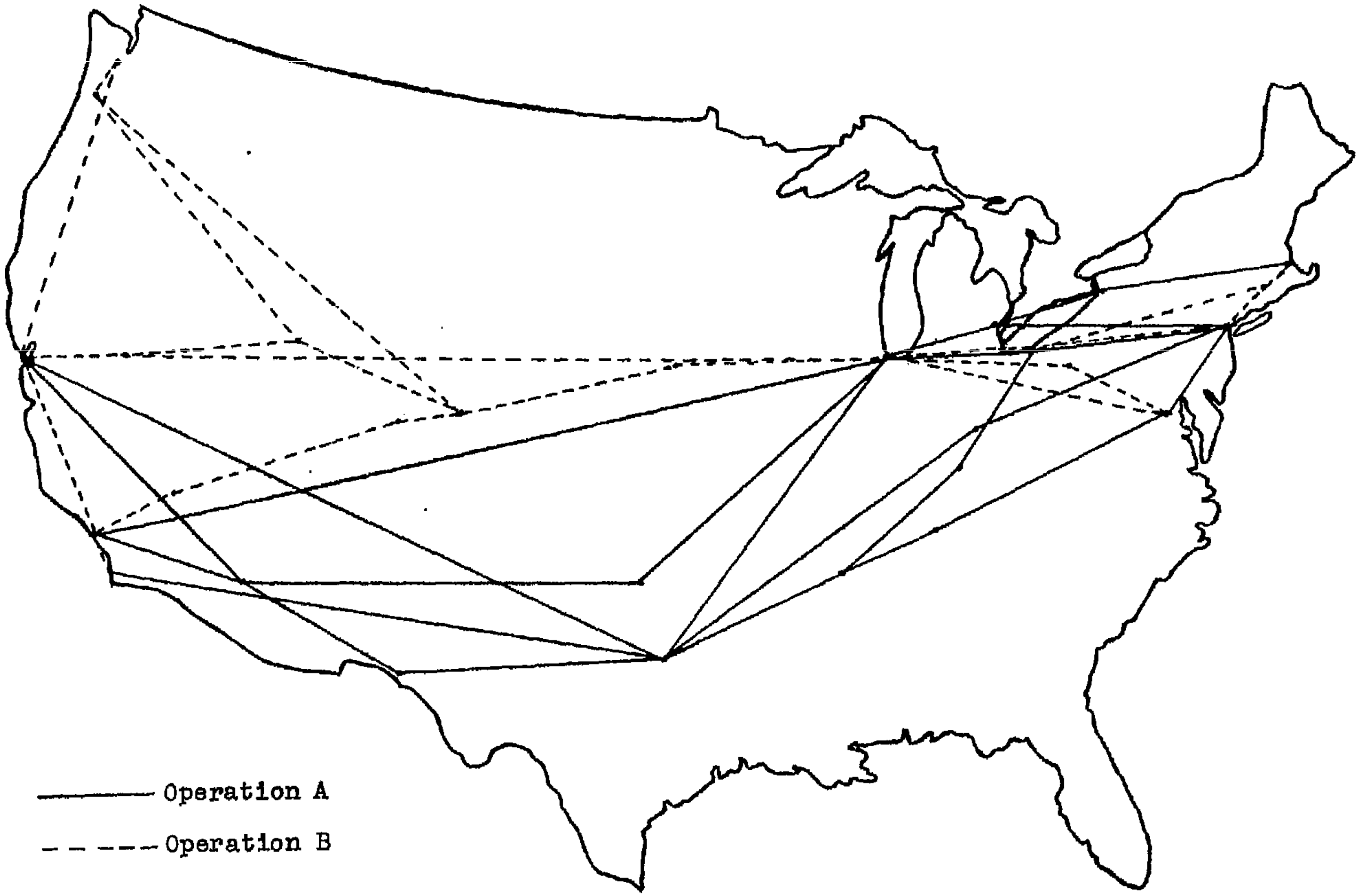


Figure 1.- Routes covered by operations A and B.

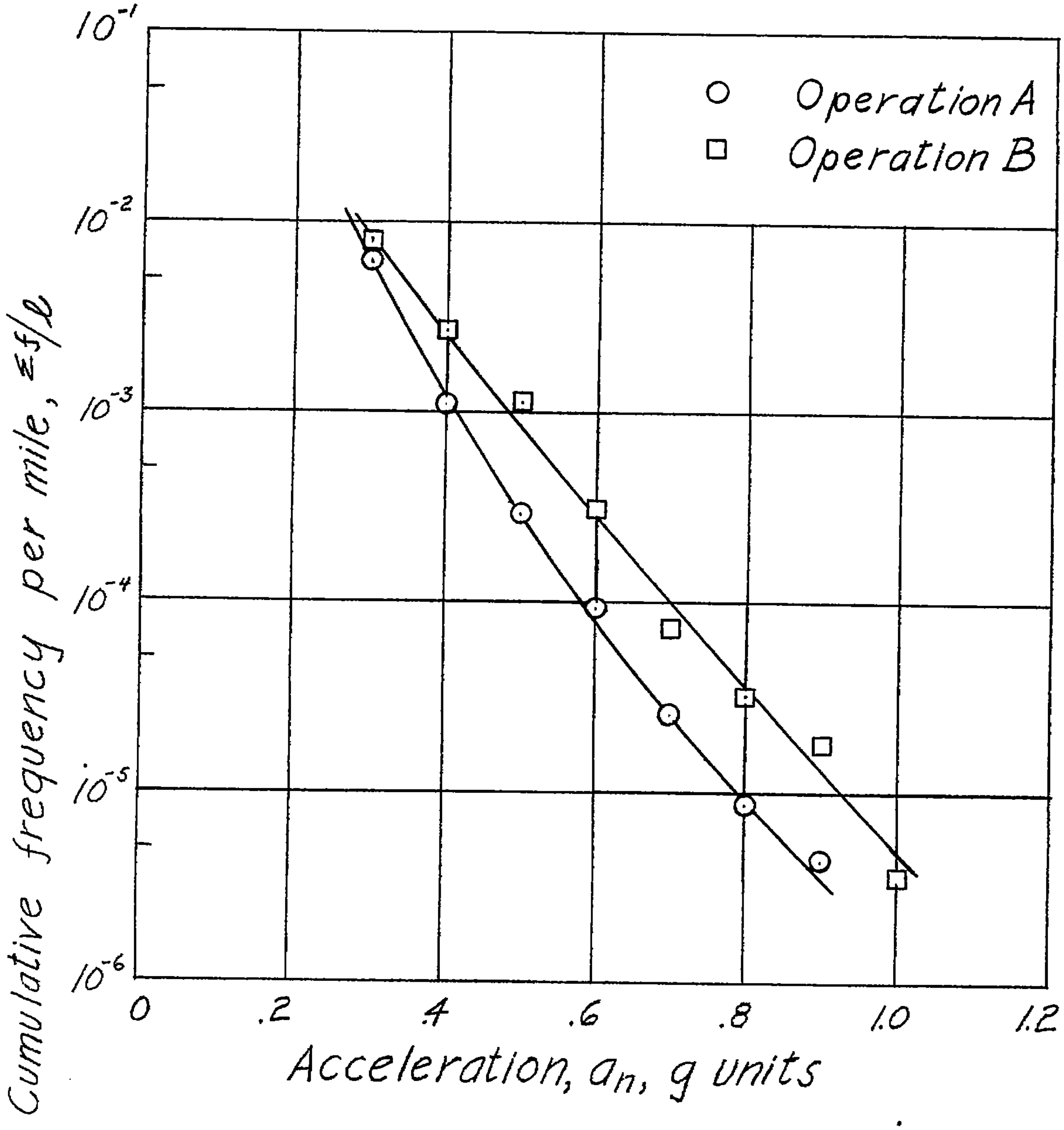
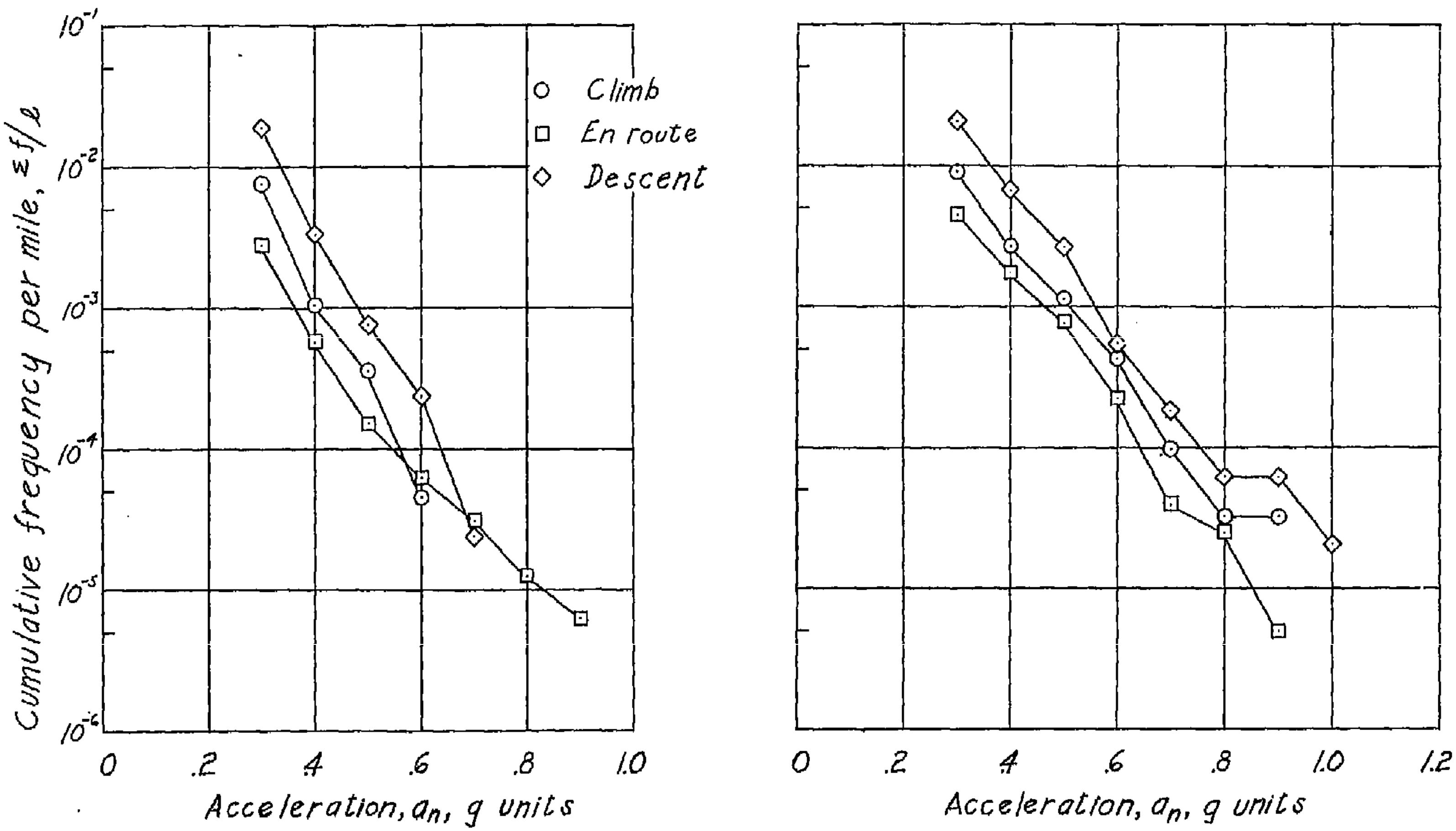


Figure 2.- Comparison of frequency of exceeding given values of gust acceleration per mile of flight for two operations.



(a) Operation A.

(b) Operation B.

Figure 3.- Comparison of frequency of exceeding given values of gust acceleration per mile of flight during climb, en route, and descent for two operations.

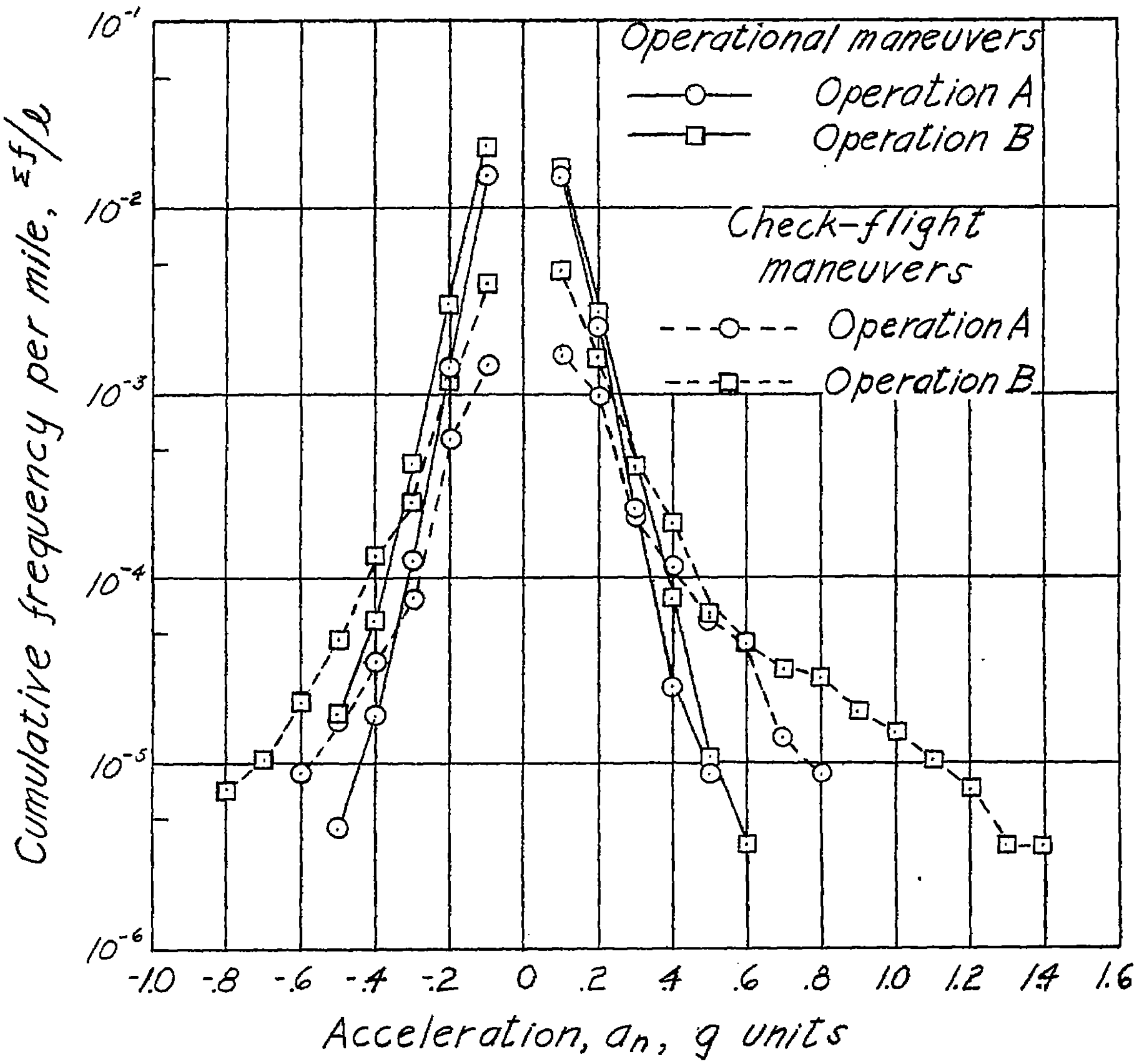
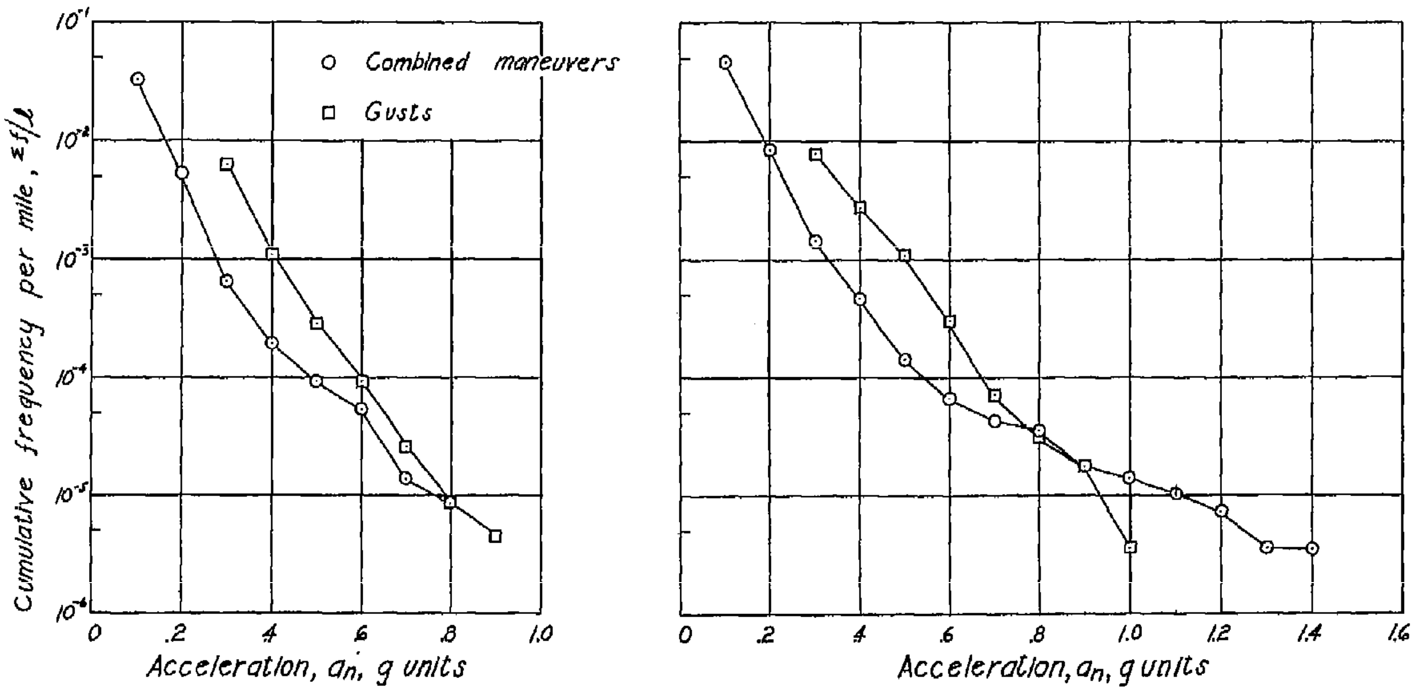


Figure 4.- Comparison of frequency of exceeding given values of operational- and check-flight-maneuver accelerations per mile of flight for two operations.



(a) Operation A.

(b) Operation B.

Figure 5.- Comparison of frequency of exceeding given values of gust and combined maneuver accelerations per mile of flight for two operations.

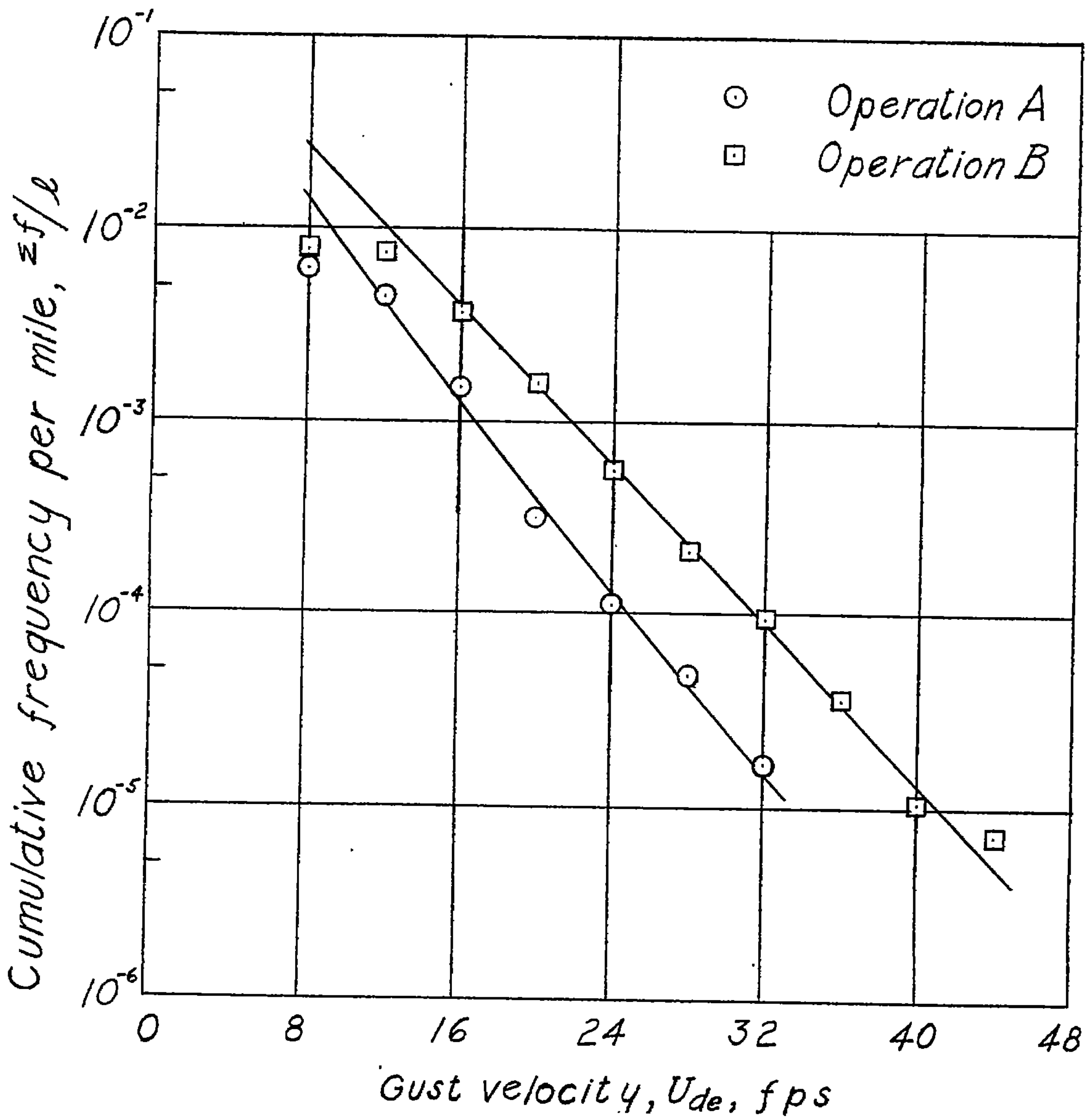
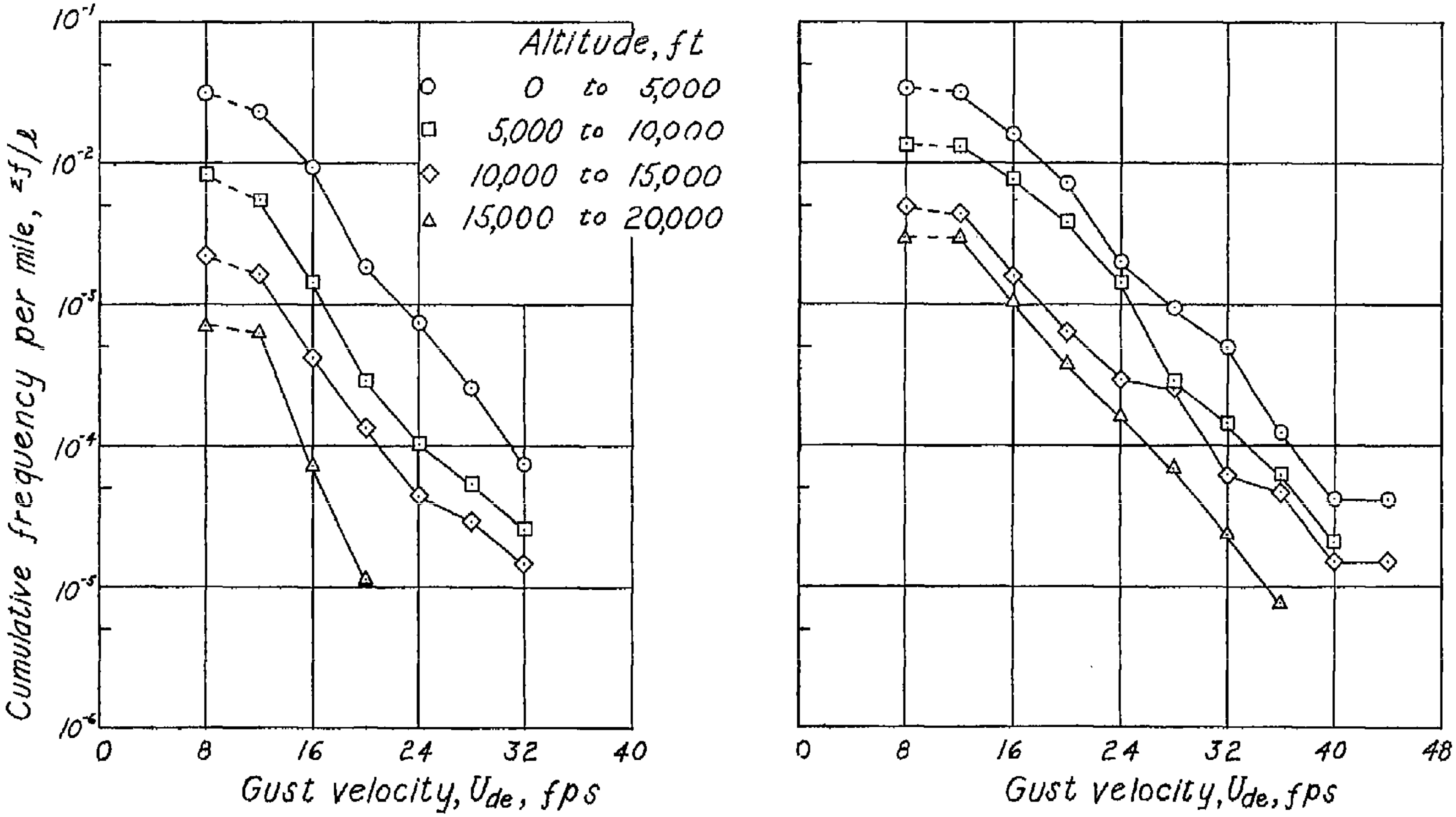
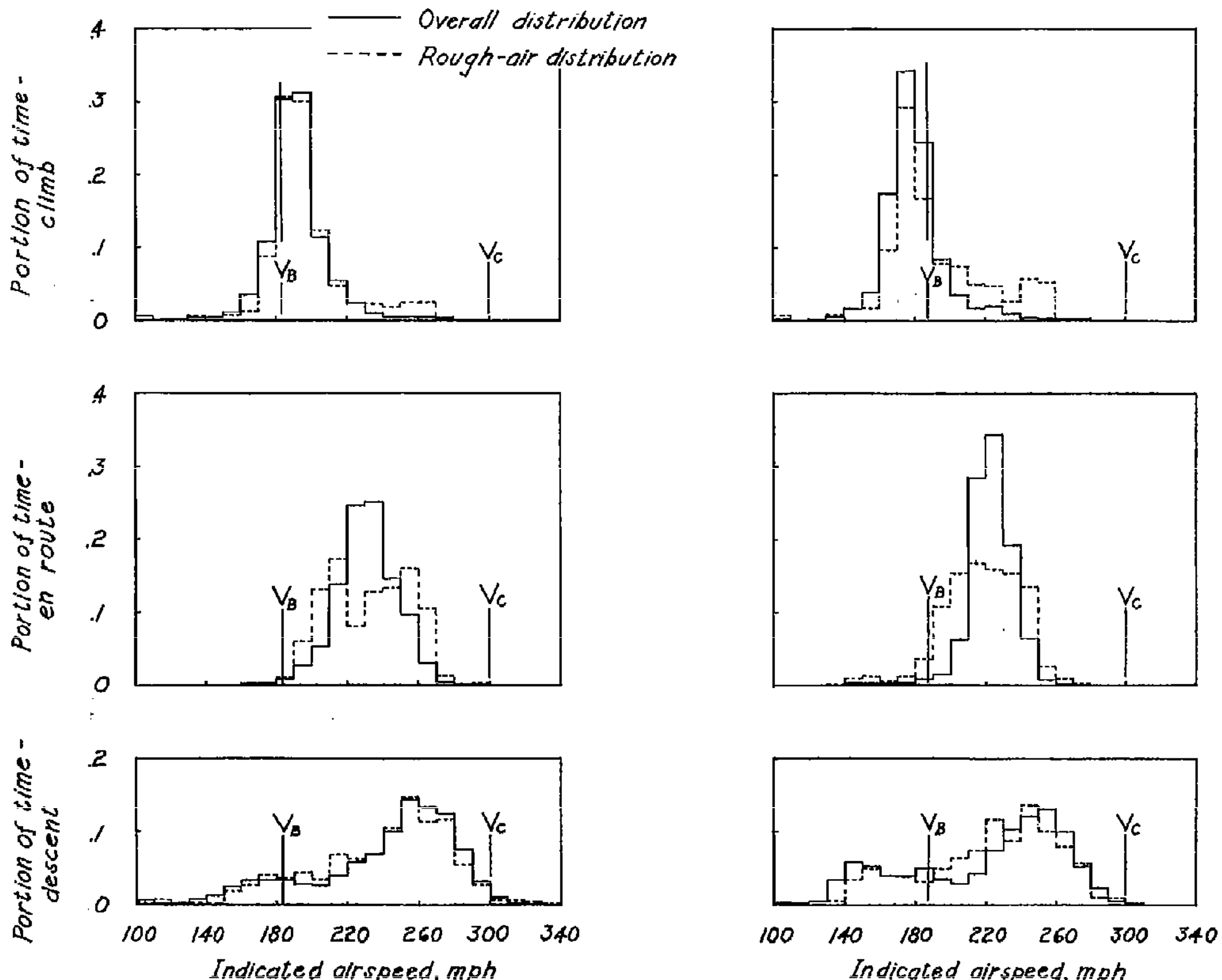


Figure 6.- Comparison of frequency of exceeding given values of gust velocity per mile of flight for two operations.



(a) Operation A. (b) Operation B.

Figure 7.- Comparison of frequency of exceeding given values of gust velocity per mile of flight with pressure altitude for two operations.



(a) Operation A.

(b) Operation B.

Figure 8.- Comparison of distributions of overall airspeed with distributions of airspeed in rough air by flight condition for two operations.

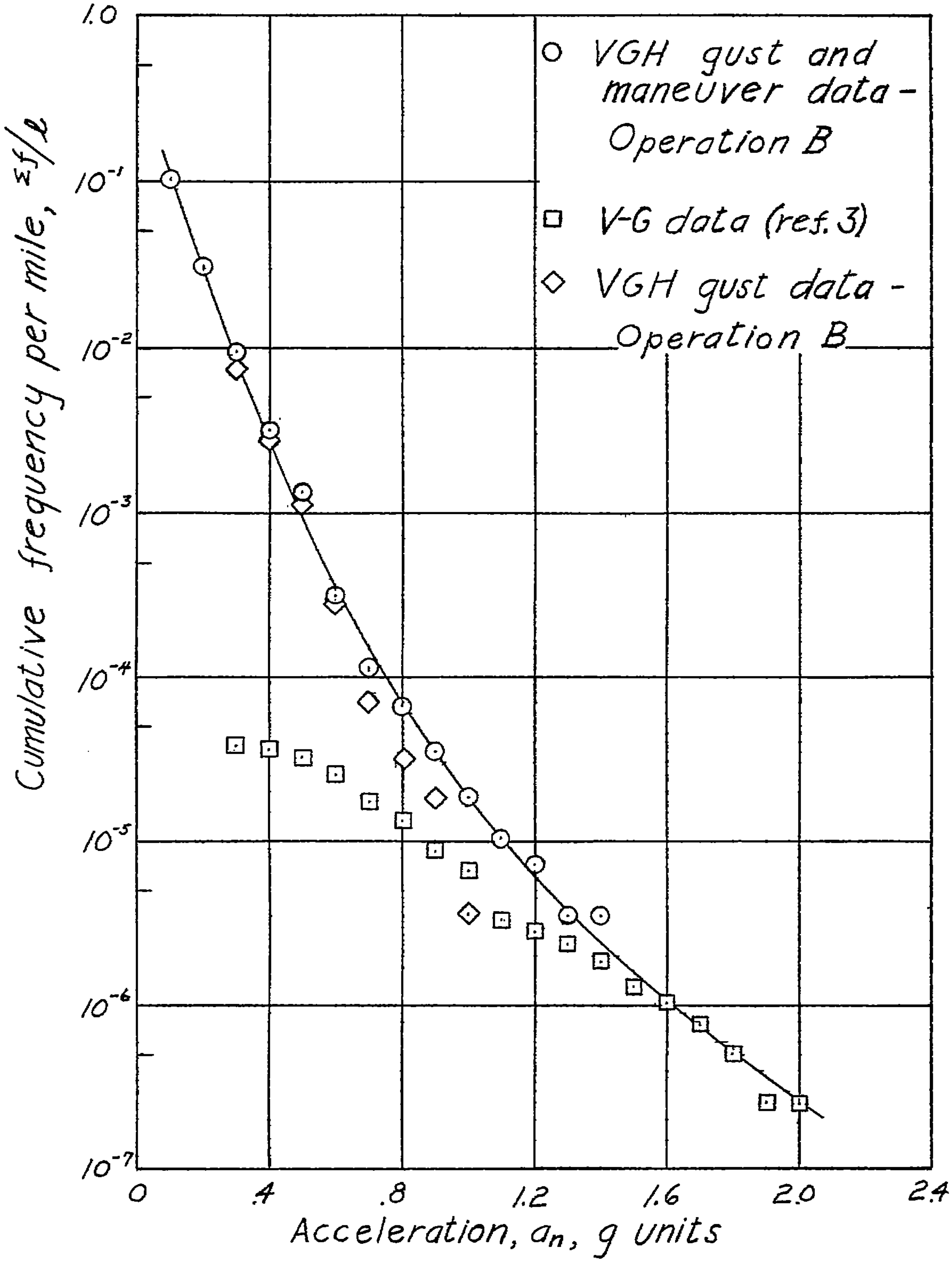


Figure 9.- Composite curve of frequency of exceeding given values of acceleration per mile of flight.

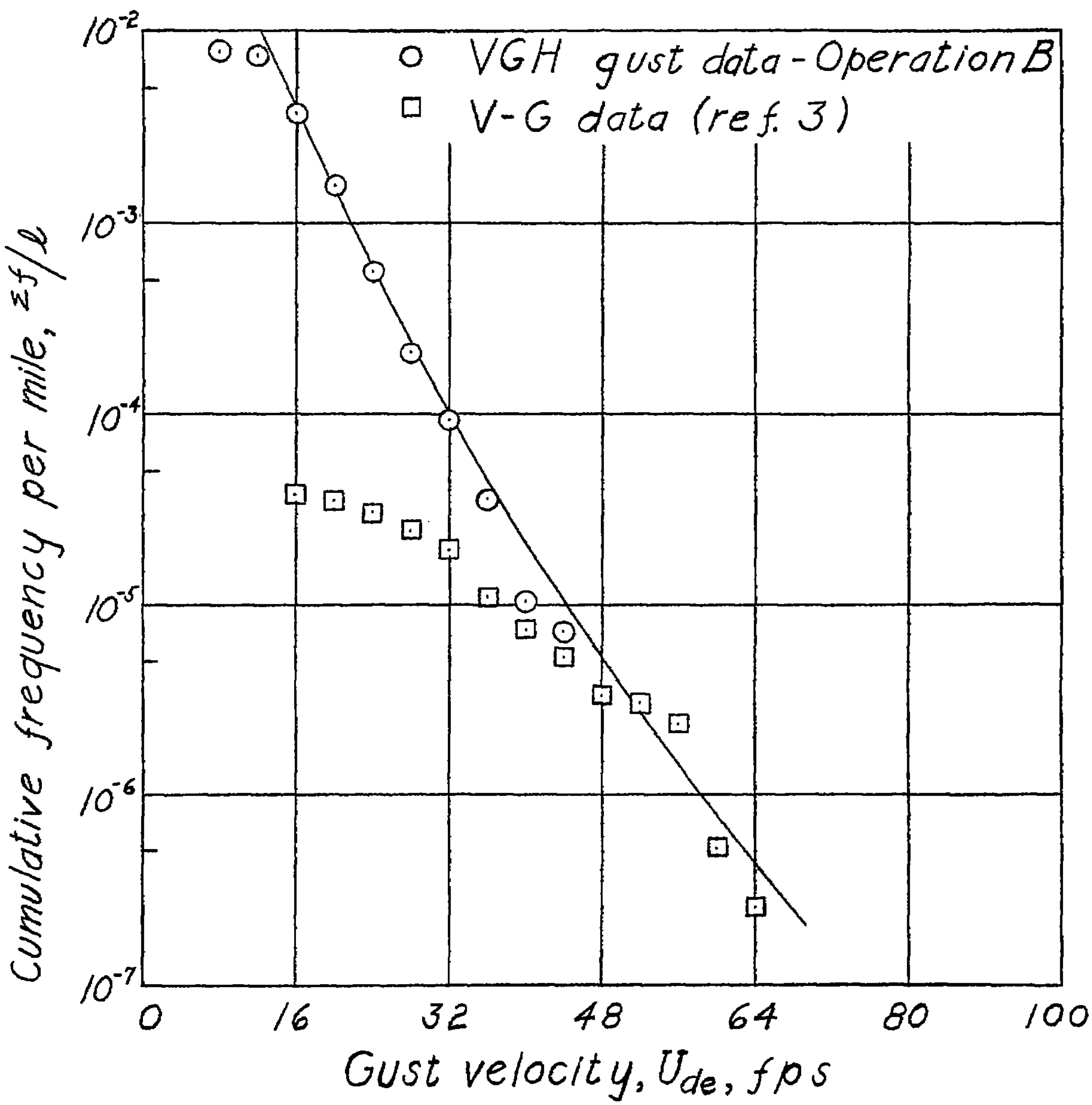


Figure 10.- Composite curve of frequency of exceeding given values of gust velocity per mile of flight.

NACA - Langley Field, Va.